TECHNICAL BULLETIN No. 25 NOVEMBER, 1927

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

EXPERIMENTS FOR THE CONTROL OF THE EUROPEAN RED MITE AND OTHER FRUIT-TREE MITES

By E. J. NEWCOMER and M. A. YOTHERS, *Associate Entomologists*
Division of Deciduous Fruit Insects, Bureau of Entomology

CONTENTS

	Page		Page
Introduction	1	Spray injury	24
Dormant sprays	2	Composition of spray materials	29
Laboratory tests	2	Oils	29
Orchard tests	5	Oil emulsions and miscible oils	30
Summer sprays	8	Miscellaneous sprays	31
Laboratory tests of sprays on the summer eggs	8	Summary and conclusions	32
Laboratory tests of sprays on the mites	10	Key to tables	33
Comparison of sulphur and oil sprays	19		
Orchard tests	20		

INTRODUCTION

Mites, or "red spiders," have long been recognized as important and insidious fruit-tree pests. The damage they do, which consists primarily of removing sap and chlorophyll from the foliage and sometimes from the fruit, is often underestimated because there is also an indirect injury. There is not only an immediate effect on fruit and foliage but also a more subtle effect on fruit buds and on the tree itself; for defoliation or serious interference with the functions of the leaves, a common result of infestations of mites, affects the development of fruit buds and the growth of the tree.

It was for these reasons that a study of the biology [1] and control of the European red mite (*Paratetranychus pilosus* C. & F.) was undertaken by the Bureau of Entomology, at Yakima, Wash.

Three species of fruit-tree mites occur commonly in the West. These are the common red spider or two-spotted mite (*Tetranychus bimaculatus* Harvey), the brown mite or clover mite (*Bryobia praetiosa* Koch), and the European red mite (*Paratetranychus pilosus* C. & F.). The control experiments detailed in this bulletin were conducted for the most part against the European red mite, since it is found in the vicinity of Yakima more commonly than the other species. The dormant sprays on the eggs of the European mite and those of the brown mite gave about equal results. The summer

[1] The biological studies are to be published as a separate bulletin

57024°—27——1

sprays found to be effective against the European mite should be equally effective against the other species.

This bulletin covers work done at Yakima, Wash., during the seasons of 1923, 1924, and 1925. It is not to be considered the final word on the control of fruit-tree mites, for the very great interest in oil sprays at the present time (1926) is sure to result in many improvements in these materials in the course of the next few years.

DORMANT SPRAYS

The European red mite and the brown mite pass the dormant season in the form of winter eggs on the trees. It seemed very probable that a dormant spray could be applied that would kill most of these eggs, and thereby to a great extent prevent the summer infestation.

LABORATORY TESTS

Laboratory tests on the winter eggs are necessary to obtain definite information as to the percentage of eggs killed by the various spray materials. In the orchard there are invariably many dead and hatched eggs that interfere with making accurate counts, and the results there can only be estimated. Accordingly, laboratory tests of various sprays were made in 1923, 1924, and 1925. Twigs with a medium infestation of eggs were selected, and with the aid of a binocular microscope the dead and hatched eggs were removed. The twigs were then sprayed and set in jars of water until finally examined. This is the method used by Garman [2] in Connecticut.

In 1923 the sprayed twigs were kept in an unheated room having approximately the same temperature and humidity as outdoors. Examination of the eggs was made after hatching on the unsprayed twigs was completed. Table 1 gives the results of this examination. The lime-sulphur spray was relatively ineffective, except at the 5° Baumé dilution. The lubricating-oil sprays were very effective at all the dilutions tested. Even when 6.5 per cent of oil was used, however, some of the eggs hatched, and in none of the tests made was an efficiency of 100 per cent obtained; for, when the final examination was made, a few eggs were found to have hatched in spite of the spray. The addition of cresol to the oil sprays did not improve them, but apparently made them slightly less effective against the eggs. The results in tests 6 to 8, where various quantities of cresol were added to a 2 per cent oil spray, were not so good as those in test 4, where no cresol was used, and with one exception the results in tests 9 to 11, where cresol was added to a 4 per cent oil spray, were inferior to those in test 5, where this spray was used without cresol. The cresol was added at the time the emulsion was made, and it appeared to mix in perfectly. The addition of cresol to a soap emulsion in this manner is not comparable to its use in a miscible oil. The kerosene spray (test 15) was fairly effective, but the distillate emulsion (tests 13 and 14) was of practically no value.

[2] GARMAN, P. NOTES ON THE EUROPEAN RED MITE. Conn. State Agr. Expt. Sta. Bul. 234: 146-152. 1922.

TABLE 1.—*Laboratory tests of dormant sprays on the winter eggs of the European red mite, Yakima, Wash., 1923*

Test No.	Material used	Dilution	Date twigs were—		Eggs		Total eggs	Eggs dead
			Sprayed	Counted	Hatched	Dead		
1	Lime-sulphur (26° Baumé concentrate)	°*B.* 3	Mar. 17	Apr. 26	*Number* 175	*Number* 203	*Number* 378	*Per cent* 53.7
2	do	4	do	do	88	215	303	71.0
3	do	5	do	do	21	266	287	92.7
4	Lubricating-oil emulsion (soap emulsifier) [1]	*P. ct. oil* 2	Mar. 9	Apr. 20	6	234	240	97.5
5	do	4	do	do	13	291	304	95.7
6	Material used in test 4, plus ¼ per cent cresol [2]	2	Mar. 14	Apr. 21	9	223	232	96.1
7	Material used in test 4, plus ½ per cent cresol [2]	2	do	do	20	358	378	94.7
8	Material used in test 4, plus 1 per cent cresol [2]	2	do	do	27	263	290	90.7
9	Material used in test 4, plus ¼ per cent cresol [2]	4	do	do	14	233	247	94.3
10	Material used in test 4, plus ½ per cent cresol [2]	4	do	do	16	277	293	94.5
11	Material used in test 4, plus 1 per cent cresol [2]	4	do	do	7	286	293	97.6
12	Material used in test 4, plus 6 per cent cresol	6.5	do	Apr. 26	6	288	294	98.0
13	Commercial distillate-oil emulsion [3]	1.6	Mar. 9	do	116	94	210	44.8
14	do	4.1	do	do	111	127	238	53.4
15	Commercial kerosene emulsion [4]	4	Mar. 20	do	39	227	266	85.3
16	Check			Apr. 20	159	71	230	30.9
17	do			May 1	101	66	167	39.5

[1] No. 4. (See p. 30.)
[2] Cresylic acid, 97 to 99 per cent, pale.
[3] No. 8. (See p. 30.)
[4] Not analyzed, but contained about 80 per cent of kerosene.

In 1924 some of the sprayed twigs were kept indoors, and some of them were placed outdoors, since it was found, in making some similar tests against the San Jose scale, that a higher percentage of the scales died indoors than out. This was discovered after tests 1 to 15 (Table 2) had been started, and therefore a second series was conducted about a month later (tests 16 to 25), and the twigs were kept outdoors. A lower percentage of the eggs hatched in the latter series, even in the check, indicating that the viability of the eggs used in this series was less. The twigs for the two series were obtained from different orchards. There is no indication that the mortality was increased by keeping the twigs indoors, but Garman[3] obtained somewhat poorer results, as a rule, in outdoor tests than in indoor tests. The difference in most cases, however, was not great.

The tests in 1924 corroborate those made in 1923, for the most part. The 5° and 6° lime-sulphur sprays gave very poor results, however, although the 1923 tests had indicated that strong lime-sulphur mixture might be effective. The oil emulsions made with soap and with casein spreader and the miscible oils gave very similar results at equivalent dilutions, and in most cases slightly better results were obtained with the 3 per cent than with the 2 per cent dilution. In the indoor tests the red engine oil, which is a heavier oil than the brown neutral oil,[4] gave better results than the brown neutral oil. Red

[3] GARMAN, P. Op. cit.
[4] See p. 29 for comparative characteristics of these oils.

engine oil was used in tests 5, 6, 7, and 9, and brown neutral oil in tests 4, 8, 10, 11, and 12. In the outdoor tests the results were about the same with both oils. Results with the two commercial preparations tried (tests 12, 13, and 14) did not equal those with the home-made mixtures.

TABLE 2.—*Laboratory tests of dormant sprays on the winter eggs of the European red mite, Yakima, Wash., 1924*

[Indoor tests. Twigs sprayed March 7, examined May 2]

Test No.	Material used	Dilution	Eggs		Total eggs	Eggs dead
			Hatched	Dead		
		°*B.*	*Number*	*Number*	*Number*	*Per cent*
1	Lime-sulphur (30° Baumé concentrate)	4	400	86	486	17.7
2	do	5	261	59	320	18.4
3	do	6	407	143	550	26.0
		Per cent oil				
4	Lubricating-oil (brown neutral)[1] emulsion (soap emulsifier)	2	65	420	485	86.6
5	Lubricating-oil (red engine)[2] emulsion (soap emulsifier)	2	26	904	930	97.2
6	do	3	25	404	429	94.2
7	do	4	20	471	491	95.9
8	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier)	2	68	467	535	87.3
9	Miscible oil[3]	2	24	490	514	95.3
10	do[4]	2	59	307	366	83.9
11	do	3	57	366	423	86.5
12	Commercial lubricating-oil (brown neutral)[1] emulsion[5]	2	77	385	462	83.3
13	Commercial spray oil[6]	2.3	99	313	412	76.0
14	do	4	22	224	246	91.1
15	Check	----------	347	25	372	6.7

[Outdoor tests. Twigs sprayed April 4; examined May 2]

		°*B.*				
16	Lime-sulphur (30° Baumé concentrate)	5	150	235	385	61.0
17	do	6	140	332	472	70.3
		Per cent oil				
18	Lubricating-oil (red engine)[2] emulsion (soap emulsifier)	2	17	1,013	1,030	98.3
19	Lubricating-oil (brown neutral)[1] emulsion (soap emulsifier)	2	4	383	387	99.0
20	do	3	24	970	994	97.6
21	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier)	2	20	1,061	1,081	98.1
22	do	3	3	485	488	99.4
23	Miscible oil[4]	2	10	407	417	97.6
24	do	3	14	1,086	1,100	98.7
25	Check	----------	561	336	897	37.5

[1] No. 1. (See p. 29.)
[2] No. 2.
[3] No. 9.
[4] No. 10
[5] No. 7.
[6] No. 11.

In the spring of 1925 winter eggs of the European red mite were difficult to find in large numbers, owing to the prevalence of predacious enemies in the fall of 1924. Therefore eggs of the brown mite were used for the laboratory tests. The twigs in these tests were kept outdoors after they had been sprayed. The results were very similar to those obtained in the previous years, as is shown in Table 3. The lime-sulphur mixture failed to kill many eggs, whereas the oil sprays were very effective. The addition of casein spreader at the rate of 1 pound to 200 gallons apparently decreased slightly the effectiveness of the 2 per cent and 3 per cent oil sprays. No advantage resulted from the addition of weak lime-sulphur mixture to the 2 per cent sprays in tests 8 and 9.

TABLE 3.—*Laboratory tests of dormant sprays on the winter eggs of the brown mite, Yakima, Wash., 1925*

[Twigs sprayed March 6; examined April 18]

Test No.	Material used	Dilution	Eggs		Total eggs	Eggs dead
			Hatched	Dead		
		°*B.*	*Number*	*Number*	*Number*	*Per cent*
1	Lime-sulphur (28° Baumé concentrate)	5	343	73	416	17.5
		Per cent oil				
2	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier)	2	31	726	757	95.9
3	do	3	23	496	519	95.6
4	do	4	51	795	846	94.0
5	Material used in test 2, plus casein spreader,[2] 1 pound to 200 gallons	2	32	523	555	94.2
6	do	3	14	240	254	94.5
7	do	4	13	259	272	95.2
8	Material used in test 2, plus lime-sulphur, 1 gallon to 50 gallons	2	23	526	549	95.8
9	Material used in test 2, plus lime-sulphur, 1 gallon to 25 gallons	2	33	671	704	95.3
10	Check		93	12	105	11.4

[1] No. 1. (See p. 29.) [2] Commercial spreader containing 20 to 25 per cent casein.

ORCHARD TESTS

A number of orchard tests were made in 1923 and 1924 to determine the practical difference between oil sprays and lime-sulphur in controlling the winter eggs of the European red mite. Since definite counts of the eggs could not be made the results were determined by counts of the mites present on leaves selected at random from the trees at various times after the eggs had hatched, and in one case by a comparison of the number of apples on which winter eggs were deposited the following fall.

The orchard used in 1923 had been only moderately infested with mites, but the mites were sufficiently numerous to indicate the value of the sprays used. The spraying was done with a power sprayer on March 30, when the leaves were beginning to show green. About 40 apple trees were sprayed with each material. No injury resulted to any of the trees.

Examinations of the sprayed plots were made April 24, May 1, and July 2 (Table 4). On the first two dates, only mites of the first brood were present, and the numbers found on the two dates were very similar. On July 2, mites of the third and fourth broods were present in the orchard. The infestation at this time was more scattered, that is, more leaves were infested, but the total number of mites present was about the same as earlier. On each date, 100 leaves from each plot were examined, 10 leaves being taken at random from each of 10 trees. The trees sprayed with lime-sulphur in plot 1 were not so heavily infested as the check trees, an indication that the lime-sulphur had been of some benefit, either in killing the eggs or in killing the young as they hatched. The trees in plots 2 and 3, sprayed with oil, were comparatively free from mites. Even in July the infestation in plot 3 was only one-third that on the unsprayed trees, and in plot 2 it was almost negligible. The results obtained do not justify any conclusion as to the effect of the cresol used in the spray applied in plot 3.

In the fall it was noticed that the mites deposited many winter eggs about the calyxes of the apples, and it was decided to examine some of these to determine whether any difference existed in the various plots. Unfortunately, most of the fruit was picked and removed from the orchard before this could be done, but some fruit was examined in plots 1 and 3, and the results, given in Table 5, are rather striking. In plot 1, where the lime-sulphur was used, winter eggs were found on 98 per cent of the fruit, whereas in plot 3, which had been sprayed with oil emulsion, only 14.4 per cent of the fruit bore winter eggs.

TABLE 4.—*Orchard tests of dormant sprays on the winter eggs of the European red mite, Yakima, Wash., 1923*

[One hundred leaves examined on each date]

Test No.	Material and dilution	Leaves examined April 24				Leaves examined May 1				Leaves examined July 2	
		Leaves infested	Total mites	Average mites per infested leaf	Average mites per leaf	Leaves infested	Total mites	Average mites per infested leaf	Average mites per leaf	Total mites	Average mites per leaf
		No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
1	Lime-sulphur (32° Baumé concentrate) diluted to 4°B	32	63	1.98	0.63	52	110	2.12	1.10	158	1.58
2	Lubricating-oil emulsion (2 per cent oil) [1]	10	22	2.20	.22	24	36	1.50	.36	4	.04
3	Material used in test 2, plus 0.25 per cent cresol	15	15	1.00	.15	9	11	1.22	.11	65	.65
4	Check	60	237	3.95	2.37	60	197	3.28	1.97	206	2.06

[1] No. 4. (See p. 30.)

TABLE 5.—*Orchard tests of dormant sprays on the winter eggs of the European red mite, Yakima, Wash., 1923*

[Fruit examined for infestation in fall]

Test No.	Material and dilution	Fruits examined	Fruits infested	Fruit infested
		Number	*Number*	*Per cent*
1	Lime-sulphur (32° Baumé concentrate), diluted to 4°B	300	294	98.0
3	Lubricating-oil emulsion (2 per cent oil) [1] plus cresol 0.25 per cent	500	72	14.4

[1] No. 4. (See p. 30.)

In 1924 a very heavily infested orchard was used for the dormant-spray tests. The trees were, in alternating rows, Rome apples and Beurre Bosc and Anjou pears, and all had been about equally infested the previous year. By means of a power sprayer about 40 or 50 trees were sprayed with each material on March 21, at which time the buds were beginning to open. No injury occurred.

A comparison of the plots was made in the same manner as in 1923, except that 50 apple leaves were examined and 50 pear leaves, 10 leaves being taken from each of five trees in each case. On account of the very severe infestation, no check trees were left. The results of these examinations are given in Table 6.

TABLE 6.—*Orchard tests of dormant sprays on the winter eggs of the European red mite, Yakima, Wash., 1924*

[Fifty apple leaves and 50 pear leaves were examined in each plot each time]

Test No.	Material and dilution	Number of mites on leaves						
		May 1			June 3			June 24
		Apple	Pear	Both	Apple	Pear	Both	Apple
1	Lime-sulphur (28° Baumé concentrate) diluted to 4.5° B	3,800	4,210	8,010	[1] 870	[1] 717	[1] 1,587	[1] 981
2	Miscible oil [2] diluted to 2 per cent oil	480	711	1,191	1,394	776	2,170	3,544
3	Casein-oil emulsion,[3] diluted to 2 per cent oil	611	820	1,431	492	378	870	1,651
4	Casein-oil emulsion,[3] diluted to 3 per cent oil	515	519	1,034	403	181	584	570

[1] The lime-sulphur plot was sprayed with a 0.5 per cent summer oil spray on May 5 and June 4.
[2] No. 10. (See p. 31.)
[3] No. 5.

The first examination was made on May 1. At this time all the winter eggs had hatched, and the female mites of the first brood had just started to oviposit. About seven times as many mites were present in the lime-sulphur plot as in any of the oil-sprayed plots. The 3 per cent oil appeared to have given slightly better results than the 2 per cent oil, and the miscible oil was a little better than the casein-oil emulsion.

The second examination was made on June 3. A few third-brood eggs had hatched at this time, but practically all of the mites present were of the second brood. The owner of the orchard had sprayed the lime-sulphur plot with a 0.5 per cent summer oil spray on May 5, and this had greatly reduced the infestation in this plot. For some reason the infestation was also reduced in plots 3 and 4, although these had been sprayed with nothing but lead arsenate in the meantime. The infestation had increased in plot 2, and on this date more mites were present there than in any of the other plots. Some of this increase may have come from the lime-sulphur plot, as the two were adjacent.

A third examination, of the apple trees only, was made on June 24, at which time mites of the second, third, and fourth broods were present. The infestation was therefore much greater than before, being about three times as heavy as previously, in plots 2 and 3. The increase in plot 4 was comparatively slight, and it is evident that a 3 per cent dormant oil spray is more effective than a weaker spray. The lime-sulphur plot had again been sprayed by the owner on June 4, with a 0.5 per cent summer oil spray, and in consequence the infestation had been checked. Neither of the summer sprays used on this plot was very thoroughly applied; hence the infestation was still heavy.

It was necessary to spray plots 2 and 3 on June 25 with a summer oil spray, but no summer treatment was given to plot 4 until July 30, when all of the plots were sprayed. At this time the leaves in plot 4 were still in a green, thrifty condition, whereas those in other plots were considerably bronzed. With a more moderate infestation, such as was experienced in 1923, summer spraying of the trees sprayed with oil while dormant would be unnecessary, and it is rarely if ever necessary or advisable to spray after July 1, if adequate treatment has been given earlier.

SUMMER SPRAYS

It is not possible to control the two-spotted mite with dormant sprays, and it is sometimes desirable to use measures against the other two species during the growing season. Therefore extensive tests were made at Yakima, Wash., of a number of summer sprays against both the summer eggs and the mites. Practically all these tests were made on the eggs and mites of the European red mite.

LABORATORY TESTS OF SPRAYS ON THE SUMMER EGGS

In June, 1923, a series of tests of various oil and sulphur sprays were made on the summer eggs of the European red mite, as recorded in Table 7. A portion of an infested tree was sprayed with each material, a bucket pump being used, and both surfaces of the leaves being thoroughly wetted. Examinations of the eggs were made from 10 to 14 days later, at a time when the live eggs would have hatched. There were usually some hatched eggs on the leaves when the spraying was done, and in some cases the spray did not kill all of the adult mites, and consequently new eggs were deposited between spraying and the time of examination. Therefore it was not found possible to obtain very accurate results. However, the results are rather conclusive, and it is considered that if more than 75 per cent of the eggs were found to be dead, the treatments are satisfactory. Lubricating-oil sprays containing 0.5 per cent of oil or more killed 80 to 100 per cent of the eggs, while the distillate-oil emulsion (tests 5 and 14) killed only 72 per cent and 39 per cent of the eggs in the two tests made. The lime-sulphur, at 1 gallon to 50 gallons (test 9), evidently did not kill any eggs, as fewer dead eggs were found in this test than in the check.

TABLE 7.—*Laboratory tests of sprays on the summer eggs of the European red mite, Yakima, Wash., 1923*

[Ten leaves (300 to 1,600 eggs) examined for each test.]

Test No.	Material used	Dilution	Date trees were—		Eggs dead
			Sprayed	Examined	
		Per cent oil			*Per cent*
1	Lubricating-oil (red engine) [1] emulsion (soap emulsifier)	0.5	June 19	June 29	80.5
2	do	1.0	do	do	100.0
3	do	2.0	do	do	100.0
4	Lubricating-oil (brown neutral) [2] emulsion (soap emulsifier)	0.5	do	June 28	62.5
5	Commercial distillate-oil emulsion [3]	1.6	do	do	71.6
6	Check			June 20	10.8
7	Lubricating-oil (red engine) [1] emulsion (soap emulsifier)	0.5	June 22	July 9	87.8
8	Lubricating-oil (brown neutral) [2] emulsion (soap emulsifier)	0.5	do	do	92.3
9	Lime-sulphur (32° Baumé concentrate), 1 gallon to 50 gallons		do	do	8.4
10	Check			do	12.7
11	Lubricating-oil (red engine) [1] emulsion (soap emulsifier) plus cresol,[4] 0.125 per cent	0.5	do	July 5	86.6
12	Lubricating-oil (red engine) [1] emulsion (soap emulsifier)	0.67	do	July 9	94.9
13	do	0.75	do	July 5	91.2
14	Commercial distillate-oil emulsion [3]	1.6	do	do	38.9
15	Check			do	15.5
16	Lubricating-oil (red engine) [1] emulsion (soap emulsifier), plus cresol 0.125 per cent	0.25	June 28	July 10	56.3
17	Material used in test 16, minus cresol	0.5	do	do	79.7
18	Material used in test 16	0.67	do	do	89.2
19	Check			do	24.2

[1] No. 2. (See p. 30.) [2] No. 1. [3] No. 8. [4] Cresylic acid 97 to 99 per cent, pale.

In 1924 similar tests were made in May, when a large number of eggs had been deposited on the leaves by the first brood of mites but before any of these eggs had hatched. Therefore, any hatched eggs found at the time of the examination had hatched in spite of the spray. Young trees were used and an entire tree was sprayed with each material. The only discrepancy in these tests, then, would result from eggs being deposited after the spray was applied, by mites that the spray failed to kill. The oil sprays killed practically all of the mites, and the results of these tests on the eggs are probably very accurate. The nonoil sprays, for the most part, killed very few eggs, as shown in Tables 8 and 9. It was found possible to distinguish between dead and live eggs fairly accurately, and eggs that were obviously alive were disregarded, as they must have been deposited after the spray was applied.

In the first series of tests (Table 8), over 97 per cent of the eggs were killed by lubricating-oil emulsions containing 0.5 per cent or more of oil, and 84.6 per cent with a lubricating-oil emulsion containing 0.25 per cent of oil. The miscible oil did not give so good results. When casein spreader was added to the oil sprays, the results were poorer, for the most part, than when no spreader was used.

The lime-sulphur, at 1 gallon to 75 gallons, killed only 14 per cent of the eggs, and at a dilution of 1 gallon to 50 gallons it killed 39 per cent of the eggs. Nicotine sulphate, 1 part to 800 parts, with fish-oil soap, 2 pounds to 50 gallons, killed less than 7 per cent of the eggs.

TABLE 8.—*Laboratory tests of sprays on the summer eggs of the European red mite, Yakima, Wash., 1924*

[Trees sprayed May 7–8; 10 leaves (600 to 1,700 eggs) examined for each test May 19]

Test No.	Material used	Dilution	Eggs dead	
			When spreader was not used	When spreader was used
		Per cent oil	*Per cent*	*Per cent*
1	Lubricating-oil (red engine)[1] emulsion (casein-lime emulsifier)	0.25	84.6	73.2
2	do	.5	98.8	89.7
3	do	.67	98.1	92.8
4	do	1.0	97.8	98.0
5	Lubricating-oil (brown neutral)[2] emulsion (soap emulsifier)	.5	97.6	----------
6	do	.67	98.8	----------
7	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)	.5	99.2	----------
8	do	.67	97.7	95.0
9	Miscible oil (brown neutral)[3]	.5	----------	75.6
10	do	.67	----------	96.2
		Dilution		
11	Lime-sulphur (30° Baumé concentrate)	1 to 75	----------	13.7
12	do	1 to 50	----------	38.7
13	Nicotine sulphate (40 per cent), plus soap,[4] 2 pounds to 50 gallons	1 to 800	6.8	----------
14	Check	----------	1.9	----------

[1] No. 2. (See p. 30.) [2] No. 1. [3] No. 10. [4] No. 15.

In the second series (Table 9) practically the same results were obtained as in the first. Lubricating-oil emulsion at 0.25 per cent of oil killed from 86 to 93 per cent of the eggs, and at 0.5 per cent it killed 99 per cent. There was no difference between the red engine oil and the lighter brown neutral oil in either case. The addition of

a spreader again reduced the percentage of eggs killed in most cases. The spreader was the ordinary commercial lime-casein mixture, used at the rate of 1 pound to 200 gallons. The results from the miscible oil were, again, not so good as from the oil emulsions. Lime-sulphur killed very few eggs. The results obtained with the nicotine sulphate and soap were rather variable, but they indicate that the nicotine is of no value as an ovocide and that the soap can not be depended on.

TABLE 9.—*Laboratory tests of sprays on the summer eggs of the European red mite, Yakima, Wash., 1924*

[Trees sprayed May 15; 1,000 to 1,600 eggs examined for each test May 20]

Test No.	Material	Dilution	Eggs dead	
			When spreader was not used	When spreader was used
		Per cent oil	*Per cent*	*Per cent*
1	Lubricating-oil (red engine)[1] emulsion (casein-lime emulsifier)	0.25	93.3	86.3
2	----do	.5	99.0	94.9
3	Lubricating-oil (brown neutral)[2] emulsion (soap emulsifier)	.25	86.1	89.8
4	----do	.5	98.9	90.2
5	Miscible oil (brown neutral)[3]	.5	88.9	93.4
		Dilution		
6	Lime-sulphur (30° Baumé concentrate)	1 to 50	11.0	
7	Nicotine sulphate (40 per cent), plus soap,[4] 2 pounds to 50 gallons	1 to 1,600	4.0	
8	----do	1 to 800	6.5	5.5
9	----do	1 to 1,000	49.0	
10	Fish-oil soap, 2 pounds to 50 gallons	2 to 50	70.1	
11	----do	2 to 50	19.4	
12	Check		3.4	

[1] No. 2. (See p. 30.) [2] No. 1. [3] No. 10. [4] No. 15.

LABORATORY TESTS OF SPRAYS ON THE MITES

More than 100 tests of various spray materials at various dilutions were made on the European red mite in 1923, 1924, and 1925. These included several lubricating oils both in the form of emulsions and miscible oils; distillate-oil and kerosene emulsions; sulphur, in the form of dust, wettable sulphur, colloidal sulphur, lime-sulphur, and soluble sulphur; and various other materials, including a fatty acid, casein spreader, nicotine sulphate, fish-oil soap, lye, washing powder, copper sulphate, water, and several proprietary sprays. These sprays are discussed in three groups; (1) the oil sprays, (2) the sulphur sprays, and (3) the miscellaneous sprays.

In 1923 the materials were sprayed very thoroughly on portions of infested trees with a bucket pump. Examination of the mites was made with a binocular microscope, 10 or 20 leaves being examined, depending upon the abundance of the mites, and a record was made of the condition of all mites found. In each case half the leaves were examined by one observer and half by another observer. In the case of the oil sprays and most of the miscellaneous sprays it was possible to make these examinations within 24 or 48 hours, and as the oil had a tendency to glue the mites to the leaves it is believed that the counts represent very accurately the results obtained. Examinations of mites sprayed or dusted with sulphur were usually delayed several days, as it was thought that the action of the sulphur might be slower. For this reason, and because the mites killed by the sulphur had a tendency to drop off, these results are not so accurate

as those from the oil sprays. However, a much larger number of live mites remained after being sprayed with sulphur sprays than with oil sprays (Table 22).

Since the tests in 1923 were made on portions of large trees, it was possible for the mites from unsprayed parts of the trees to migrate to the sprayed parts before the examination was made and thus influence the results. Therefore, in 1924, all the tests were made on young trees, and an entire tree was sprayed with each material used. The possibility of contamination was therefore negligible. In 1925 no infested young trees were available and the tests were made on large trees, as in 1923.

OIL SPRAYS

In June, 1923, two series of tests of oil sprays were made. Some preliminary tests, made in September, 1922, had indicated that weak lubricating-oil emulsions would be very effective against the mites, and therefore in the first series (Table 10) oil emulsions diluted to 0.5, 1, and 2 per cent of oil were used, as well as the 0.5 per cent emulsion with the addition of cresol, as it was thought that this might make the spray more effective. The cresol used is known as "cresylic acid, 97 to 99 per cent, pale." A commercial distillate-oil emulsion was also used. In the second series (Table 11) several of these tests were repeated, and red engine-oil emulsions containing 0.25, 0.67, and 0.75 per cent of oil were tested. The tests indicated that these lubricating-oil emulsions would kill from 90 to 100 per cent of the mites, if used at the dilution of 0.5 per cent or stronger, that the addition of cresol was not only of no value, but apparently hindered the action of the oil, that the lighter brown neutral oil was practically as effective as the red engine oil, and that the distillate-oil emulsion, when used at the strength recommended by the manufacturer, killed little more than half as many mites as the lubricating-oil sprays. The 0.25 per cent lubricating-oil spray killed about 80 per cent of the mites.

In August, 1923, a test was made of the red engine-oil emulsion at dilutions of 0.25 and 0.5 per cent of oil, with and without casein spreader. The spreader was used at the rate of 1 pound to 100 gallons of spray. As is shown in Table 12, the best results were obtained where no spreader was used.

TABLE 10.—*Laboratory tests of oil sprays against the European red mite, Yakima, Wash., 1923*

[Trees sprayed June 19; 10 leaves (150 to 400 mites) examined for each test June 20 and 21]

Test No.	Material used	Dilution	Mites killed
		Per cent oil	*Per cent*
1	Lubricating-oil (red engine) [1] emulsion (soap emulsifier)	0.5	92.3
2	Lubricating-oil (red engine) [1] emulsion (soap emulsifier), plus cresol, 0.125 per cent	.5	75.7
3	Lubricating-oil (red engine) [1] emulsion (soap emulsifier), plus cresol, 0.25 per cent	.5	89.9
4	Lubricating-oil (red engine) [1] emulsion (soap emulsifier)	1.0	100.0
5	do	2.0	100.0
6	Lubricating-oil (brown neutral) [2] emulsion (soap emulsifier)	.5	92.0
7	Commercial distillate-oil emulsion [3]	1.6	62.3
8	Check		6.4

[1] No. 2. (See p. 30.) [2] No. 1. [3] No. 8.

TABLE 11.—*Laboratory tests of oil sprays against the European red mite, Yakima, Wash., 1923*

[Trees sprayed June 22; 20 leaves (150 to 300 mites) examined for each test June 23]

Test No.	Material used	Dilution	Mites killed
		Per cent oil	*Per cent*
1	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)	0.5	100.0
2	Lubricating-oil (red engine)[1] emulsion (soap emulsifier), plus cresol, 0.125 per cent	.5	86.1
3	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)	.67	98.3
4	do	.75	97.9
5	Lubricating-oil (brown neutral)[2] emulsion (soap emulsifier)	.5	98.5
6	Commercial distillate-oil emulsion [3]	1.6	49.6
7	Check		7.2

[Trees sprayed June 28; 10 leaves (150 to 250 mites) examined for each test June 30]

8	Lubricating-oil (red engine) [1] emulsion (soap emusifier), plus cresol, 0.25 per cent	*Per cent oil* 0.25	*Per cent* 80.4
9	Lubricating-oil (red engine) [1] emulsion (soap emulsifier)	.5	96.7
10	do	.67	100.0
11	Check		7.8

[1] No. 2. (See p. 30.) [2] No. 1. [3] No. 8.

TABLE 12.—*Laboratory tests of oil sprays, with and without caseinate spreader, against the European red mite, Yakima, Wash., 1923*

[Trees sprayed August 13; 10 leaves (500 to 1,000 mites) examined for each test August 14]

Test No.	Materials used	Dilution	Mites killed	
			When spreader was not used	When spreader was used[2]
		Per cent oil	*Per cent*	*Per cent*
1	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)	0.25	94.9	53.0
2	do	.5	88.9	68.4
3	Check		9.9	

[1] No. 2. (See p. 30.) [2] Commercial spreader containing 20 to 25 per cent casein.

In 1924 the tests were made in a more accurate manner, as already explained. The first series of tests of lubricating-oil sprays, made May 7 and 8 (Table 13), showed that under these conditions the emulsion containing 0.25 per cent of oil killed 94 per cent of the mites; that the emulsions containing 0.5 per cent of oil or more killed 99 to 100 per cent of the mites; that there was no difference in the effectiveness of emulsions made with soap and with casein, or in emulsions made of the brown neutral or red engine oils; that the miscible oil was not quite so effective as the emulsions; and that the addition of casein spreader usually reduced the effectiveness of the oil spray. As a check on some of these points, a second series of tests was made a few days later, the results of which are given in Table 14. These tests corroborated the inferences drawn from the former tests.

The results obtained in 1923 with oil sprays, to which was added a small quantity of cresol, were not so good as those with sprays having no cresol added. In 1924 the miscible oils, which contained cresol

did not give quite so good results as the oil emulsions containing none. This indicates that the cresol may have a deleterious effect on the oil sprays, although this effect is not pronounced.

TABLE 13.—*Laboratory tests of oil sprays, with and without casein spreader, on the European red mite, Yakima, Wash., May, 1924*

[Trees sprayed May 7–8; 20 leaves (150 to 400 mites) examined for each test May 9–12]

Test No.	Material used	Dilution	Mites killed	
			When spreader was not used	When spreader was used [1]
1	Lubricating-oil (brown neutral) [2] emulsion (casein-lime emulsifier)	*Per cent oil* 0.25	*Per cent* 93.8	*Per cent* 91.0
2	do	.5	100.0	97.2
3	do	.67	100.0	100.0
4	do	1.0	99.5	99.2
5	Lubricating-oil (brown neutral) [2] emulsion (soap emulsifier)	.5	100.0	
6	do	.67	100.0	
7	Lubricating-oil (red engine) [3] emulsion (soap emulsifier)	.5	100.0	
8	do	.67	100.0	99.3
9	Miscible oil [4]	.5	97.6	79.3
10	do	.67	97.4	99.6
11	Check		4.9	

[1] Commercial spreader containing 20 to 25 per cent casein.
[2] No. 1. (See p. 29.)
[3] No. 2.
[4] No. 10.

TABLE 14.—*Laboratory tests of oil sprays, with and without casein spreader, on the European red mite, Yakima, Wash., May, 1924*

[Trees sprayed May 13; 20 leaves (100 to 200 mites) examined for each test May 15]

Test No.	Material used	Dilution	Mites killed	
			When spreader was not used	When spreader was used
1	Lubricating-oil (brown neutral) [1] emulsion (casein-lime emulsifier)	*Per cent oil* 0.25	*Per cent* 100.0	*Per cent* 97.7
2	do	.5	100.0	100.0
3	Lubricating-oil (brown neutral) [1] emulsion (soap emulsifier)	.25	98.5	98.4
4	do	.5	100.0	100.0
5	Miscible oil (brown neutral) [2]	.5	99.3	97.5
6	Check		2.2	

[1] No. 1. (See p. 29.) [2] No. 10.

In July, 1924, when the mites were more numerous, another series of tests was made. At this time the addition of both lead arsenate and casein spreader to the oil sprays was tested, as well as the addition of a weak lime-sulphur mixture. The results of these tests are recorded in Table 15. In the earlier tests of the 0.5 per cent oil emulsions without additional spreader, 100 per cent of the mites had been killed practically every time. In the July tests this did not occur, whether spreader or lead arsenate or both were added to the spray. The addition of both materials produced poorer results than either one alone, and the use of these, even with the 0.67 per cent oil spray, did not kill all of the mites. It might be thought

that the spreader would increase the chances of killing the mites by causing a more perfect coating of spray to form over them. As a matter of fact, however, every mite in the path of the spray is sure to be hit by it, and, even when no spreader was used, it was found that, after the spraying ceased, every mite and egg had a drop of spray adhering to it, though there were places on the leaves that were apparently dry. As these drops of spray dried, a film of oil was left covering each mite and egg, and it is possible that more oil adheres to the organism in this way than when the spray is left in a thin coat by the spreader. The results obtained from the addition of lead arsenate point to the possibility that the insoluble lead arsenate or the lime in the spreader may absorb enough of the oil to reduce slightly its killing power. The reduction in the effectiveness of the spray upon the addition of either material is not enough, however, to be of any practical consequence, if there is some other reason for adding these materials.

In test 5, Table 15, the addition of a weak lime-sulphur to the 0.25 per cent lubricating-oil emulsion made it completely effective against the mites.

TABLE 15.—*Laboratory tests of oil sprays against the European red mite, Yakima, Wash., July, 1924*

[Trees sprayed July 8; 10 leaves (800 to 2,200 mites) examined for each test July 9]

No.	Material used	Dilution	Mites killed
		Per cent oil	*Per cent*
1	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier), plus casein spreader,[2] 1 pound to 200 gallons	0.5	98.5
2	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier), plus lead arsenate,[3] 1 pound to 50 gallons	.5	98.9
3	Material used in test 2, plus casein spreader,[2] 1 pound to 200 gallons	.5	93.8
4	do	.67	97.8
5	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier), plus lime-sulphur, 1 to 100	.25	100.0
6	Check		11.1

[Trees sprayed July 21; 10 leaves (900 to 1,500 mites) examined for each test July 22]

		Per cent oil	*Per cent*
7	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier), plus casein spreader,[2] 1 pound to 200 gallons	0.5	99.2
8	Lubricating-oil (brown neutral)[1] emulsion (casein-lime emulsifier), plus lead arsenate,[3] 1 pound to 50 gallons	.5	98.4
9	Material used in test 8, plus casein spreader,[2] 1 pound to 200 gallons	.5	96.8
10	do	.67	98.1
11	Material used in test 7	2.0	100.0
12	Check		10.6

[1] No. 1. (See p. 29.)
[2] Commercial spreader containing 20 to 25 per cent casein.
[3] Commercial dry lead arsenate.

In 1925 a brown neutral oil emulsified with kaolin was tested (test 4, Table 16), as well as a homemade emulsion made of a colorless or crystal oil (tests 5, 11, and 12), and a commercial emulsion made of the same type of oil (tests 6 and 7). The kaolin emulsion gave perfect results. The crystal oil killed over 99 per cent of the mites at a dilution of 1 per cent or stronger, but at 0.5 per cent dilution it killed only 96 per cent of the mites. The addition of weak lime-sulphur mixture to the oil spray (tests 3 and 8) did not give quite so good

results as it gave in 1924. Since the combination burns the foliage severely, as will be shown later, it is of no practical use. A combination fatty-acid and oil emulsion, containing 0.25 per cent of oil and fatty acid at a dilution of 1 to 2,500 (test 9), did not give as good results as the oil alone (test 1), and the addition of fatty acid at a dilution of 1 to 1,200 to this oil spray (test 10) did not improve it much. The addition of casein spreader to the 0.25 per cent oil spray produced practically the same results in this case as when the spreader was not used (tests 1 and 2).

TABLE 16.—*Laboratory tests of oil sprays against the European red mite, Yakima, Wash., 1925*

Test No.	Material used	Dilution	Date trees were—		Mites examined	Mites killed
			Sprayed	Examined		
		Per cent oil			*Number*	*Per cent*
1	Lubricating-oil (brown neutral) [1] emulsion (case-in-lime emulsifier)	0.25	July 1	July 3	431	89.8
2	Material used in test 1, plus casein spreader,[2] 1 to 200	.25	do	do	377	89.7
3	Material used in test 1, plus lime-sulphur, 1 to 100	.25	do	do	229	95.6
4	Lubricating-oil (brown neutral)[1] emulsion (kaolin emulsifier) [3]	.67	do	do	317	100.0
5	Lubricating-oil (crystal) [4] emulsion (kaolin emulsifier) [3]	1.0	do	do	449	99.3
6	Commercial lubricating-oil (crystal) [4] emulsion [5]	.85	do	do	420	98.3
7	do	1.70	do	do	437	100.0
8	Material used in test 4, plus lime-sulphur, 1 to 100	.25	July 6	July 8	543	98.9
9	Lubricating oil-fatty acid emulsion [6] (fatty acid, 1 to 2,500)	.25	do	do	922	77.0
10	Material used in test 4, plus fatty-acid emulsion [7] (fatty acid, 1 to 1,200)	.25	do	do	685	91.8
11	Lubricating-oil (crystal) [4] emulsion (casein-lime emulsifier) [8]	.5	do	do	403	96.0
12	Lubricating-oil (crystal) [4] emulsion (casein-lime emulsifier) [8]	1.0	do	do	454	99.8
13	Check			July 3	927	6.0

[1] No. 1. (See p. 29.)
[2] Commercial spreader containing about 20 per cent casein.
[3] No. 6.
[4] No. 3.
[5] No. 12.
[6] No. 13.
[7] No. 14.
[8] No. 5.

SULPHUR DUSTS AND SPRAYS

In 1923 a test was made on June 19 of a dusting sulphur containing 89 per cent of sulphur and of a sulphur and nicotine dust containing 61 per cent sulphur and 2.5 per cent nicotine. As is shown in Table 17, the former killed only 17.6 per cent of the mites and the latter 19.3 per cent. The maximum temperatures between the dates of application of the dust and the dates of examination were 92° and 79° F., respectively. The dusting sulphur was tried again June 28 and August 7, the maximum temperatures being 96° and 91° F., respectively. A mortality of 17.7 per cent resulted from the first of these tests and a mortality of 27.4 per cent from the second. In these sulphur-dust tests an entire tree was dusted each time, and examinations made at intervals showed many of the mites running about over the sulphur-covered leaves with particles of dust adhering to them. The sulphur did not seem to have much effect on them, and therefore no further tests of sulphur dust were made on the European red mite.

TABLE 17.—*Laboratory tests of sulphur dusts against the European red mite, Yakima, Wash., 1923*

Test No.	Material used	Maximum temperature	Date trees were—		Mites examined	Mites killed
			Sprayed	Examined		
		°F.			*Number*	*Per cent*
1	Dusting sulphur,[1] containing 89 per cent sulphur	92	June 19	June 29	273	17.6
2	Sulphur and nicotine dust,[2] (61 per cent sulphur; 2.5 per cent nicotine)	79	---do---	June 21	114	19.3
3	Check	79	----------	June 20	110	7.3
4	Dusting sulphur,[1] containing 89 per cent sulphur	96	June 28	July 3	442	17.7
5	Check	96	----------	---do---	388	8.8
6	Dusting sulphur,[1] containing 89 per cent sulphur	91	Aug. 7	Aug. 13	786	27.4
7	Check	82	----------	Aug. 9	1,972	9.9

[1] No. 19 (See p. 32.) [2] No. 20.

In 1924 a test of dusting sulphur (89 per cent) was made against the two-spotted mite. An infested sweet-cherry tree was dusted June 29, and it was noted that the dust adhered to the webbing very well. On July 3 an examination was made, and it was found that all the two-spotted mites had been killed, the only live mite found being a stray adult European red mite. The presence of many very small dead mites indicated that the dust had killed the young as they hatched. Many live mites were found on an adjacent tree that had not been dusted. The daily maximum temperatures between the time of dusting and the examination ranged from 93° to 106° F. It is evident that under these conditions the sulphur dust is very effective against the two-spotted mite.

Table 18 gives the results obtained when various sprays of sulphur were used. Lime-sulphur (tests 1, 6, 8, and 9) killed more mites than any other form of sulphur, although in the tests made June 28 (tests 8 and 9), the percentage killed was low. A homemade colloidal sulphur (test 13) gave fair results, but no better than lime-sulphur. The wettable sulphur (tests 2 and 14) was a sulphur to which some glue or other similar material had been added by the manufacturer. It mixed well with water but killed only 22 per cent of the mites. Flowers of sulphur and sulphur flour were mixed with casein spreader, which caused them to become wettable, and tried in tests 3, 4, 10, and 11. They killed from 12 to 25 per cent of the mites. It was considered unnecessary to make any further tests of any of these materials except the lime-sulphur.

In 1924 lime-sulphur spray was tested again under more favorable conditions. Table 19 shows that when used at a dilution of 1 to 75 (test 1) it killed 67.5 per cent of the mites, and at a dilution of 1 to 50 (tests 2 and 4) it killed from 82 to 94 per cent of the mites. It is not so effective as the oil sprays, but it is worthy of consideration where there is need to use it as a fungicide. A proprietary "soluble sulphur" was tested in August, 1925 (test 6). This appeared to be a combination of sulphur and soda-fish-oil soap. It killed over 88 per cent of the mites, when used according to directions.

TABLE 18.—*Laboratory tests of sulphur sprays against the European red mite, Yakima, Wash., 1923*

Test No.	Material used	Dilution	Maximum temperature	Date trees were—		Mites examined	Mites killed
				Sprayed	Examined		
			°F.			*Number*	*Per cent.*
1	Lime-sulphur, 32° Baumé concentrate	1 to 50 [1]	79	June 19	June 21	182	78.6
2	Wettable sulphur	5 to 100 [2]	81	do	June 27	129	21.7
3	Flowers of sulphur, plus casein spreader, one-half pound to 100 gallons.	5 to 100 [2]	81	do	do	134	11.9
4	Sulphur flour, plus casein spreader, one-half pound to 100 gallons.	5 to 100 [2]	81	do	do	83	25.3
5	Check		81		do	325	11.4
6	Lime-sulphur, 32° Baumé concentrate	1 to 50 [1]	74	June 22	June 23	127	88.2
7	Check		74		June 22	166	7.2
8	Lime-sulphur, 32° Baumé concentrate	1 to 100 [1]	96	June 28	July 3	402	43.8
9	do	1 to 50 [1]	96	do	do	551	35.8
10	Flowers of sulphur, plus casein spreader, one-half pound to 100 gallons.	5 to 100 [2]	96	do	do	320	18.4
11	Sulphur flour, plus casein spreader, one-half pound to 100 gallons.	5 to 100 [2]	96	do	do	490	13.9
12	Check		96		do	388	8.8
13	Colloidal sulphur [3]		82	Aug. 7	Aug. 9	650	65.4
14	Wettable sulphur	5 to 100 [2]	91	do	Aug. 13	1,003	22.0
15	Check		82		Aug. 9	1,972	9.9

[1] Gallons to gallons. [2] Pounds to gallons. [3] No. 18. (See p. 32.)

TABLE 19.—*Laboratory tests of sulphur sprays against the European red mite, Yakima, Wash., 1924 and 1925*

[Tests 1 to 5 were made in 1924; tests 6 and 7 were made in 1925]

Test No.	Material used	Dilution	Maximum temperature	Date trees were—		Mites examined	Mites killed
				Sprayed	Examined		
			°F.			*Number*	*Per cent*
1	Lime-sulphur, 28° Baumé concentrate, plus casein spreader, one-half pound to 100 gallons.	1 to 75	88	May 7	May 9	83	67.5
2	do	1 to 50	88	do	do	248	81.9
3	Check		88		May 10	512	4.9
4	Lime-sulphur, 28° Baumé concentrate	1 to 50	91	May 13	May 15	139	93.5
5	Check		91		do	182	2.2
6	Soluble sulphur [1]	4 to 50 [2]	96	Aug. 17	Aug. 19	374	88.5
7	Check		96		do	564	33.3

[1] Not analyzed. [2] Pounds to gallons.

MISCELLANEOUS SPRAYS AND DUSTS

In 1923 a series of tests of materials containing nicotine and soap was made, and another series was made in 1924. The results of these tests are given in Table 20. A nicotine dust (test 1) was of practically no value, and a nicotine-sulphur dust (test 2) was not very much better. Nicotine sulphate, at a solution of 1 to 800, with casein as a spreader (test 4), killed 44.3 per cent of the mites, and a solution containing nicotine and casein having the same strength of nicotine (test 5) killed 47.2 per cent. A commercial preparation containing nicotine and creosote (test 6) killed 38 per cent.

Nicotine sulphate has been recommended as a remedy for mites at various times, and it seemed possible that the soap ordinarily used as

a spreader might be the more active part of this combination. This was tested in 1924, and it was found that potash fish-oil soap was much more effective than the nicotine sulphate alone or with casein spreader. (Compare tests 10, 16, and 20 with 13, 14, 15, and 18.) It required 2 pounds of the soap to 50 gallons of water to be effective, 1 pound being much less effective (tests 20 and 21). The addition of 2 pounds of this fish-oil soap to 50 gallons of spray containing nicotine sulphate 1 to 800 or 1 to 1,000, made a very effective spray (tests 8 and 9), but since the soap kills most of the mites, it would not pay to use the nicotine unless aphids were present also.

Several other materials were tried. Calcium caseinate in the ordinary commercial form, made for use as a spreader, was tried at 1 pound to 100 gallons (test 1, Table 21), but it had very little effect. Water was tried (tests 2 and 9), but no more dead mites were found than often occur on unsprayed leaves. A washing soda (sodium carbonate) used at the rate of 1 pound to 100 gallons (test 4) killed over 50 per cent of the mites, while lye (sodium hydroxide) at the same dilution (test 5) killed only about 37 per cent. Copper sulphate was tested at dilutions of 1 pound to 200 gallons and 1 pound to 100 gallons, but had very little more effect than water (tests 7, 8, and 9).

TABLE 20.—*Laboratory tests of nicotine and soap sprays and dusts against the European red mite, Yakima, Wash., 1923 and 1924*

[Tests 1 to 7 were made in 1923; tests 8 to 22 were made in 1924]

Test No.	Material used	Dilution	Maximum temperature	Date trees were—		Mites examined	Mites killed
				Sprayed	Examined		
		Per cent	°F.			*Number*	*Per cent*
1	Nicotine dust [1] (2 per cent nicotine)		79	June 19	June 21	132	8.3
2	Nicotine-sulphur dust,[2] (2.5 per cent nicotine, 61 per cent sulphur).		79	do	do	114	19.3
3	Check		79		do	110	7.3
4	Nicotine sulphate (40 per cent), plus casein spreader,[3] 1 to 200.	1 to 800	82	Aug. 7	Aug. 9	775	44.3
5	Nicotine caseinate [4]	1 to 800	82	do	do	716	47.2
6	Commercial nicotine-creosote preparation.[5]	1 to 800	82	do	do	941	38.0
7	Check		82		do	1,972	9.9
8	Nicotine sulphate (40 per cent), plus potash fish-oil soap,[6] 2 to 50.	1 to 1,000	91	May 13	May 15	125	100.0
9	do	1 to 800	88	May 7	May 9	600	99.0
10	Potash fish-oil soap [6]	[7] 2 to 50	91	May 13	May 15	169	98.8
11	Check		88		May 10	512	4.9
12	do		91		May 15	182	2.2
13	Nicotine sulphate (40 per cent)	1 to 1,600	91	May 15	May 16	66	47.0
14	do	1 to 800	91	do	do	91	63.7
15	Nicotine sulphate (40 per cent), plus casein spreader,[3] 1 to 200.	1 to 800	91	do	do	86	77.9
16	Potash fish-oil soap [6]	[7] 2 to 50	91	do	do	85	89.4
17	Check		91		do	285	6.7
18	Nicotine sulphate (40 per cent), plus casein spreader,[3] 1 to 200.	1 to 2,000	88	July 8	July 9	666	33.8
19	Material used in test 18, plus potash fish-oil soap,[6] 1 to 50.	1 to 2,000	88	do	do	846	78.7
20	Potash fish-oil soap [6]	[7] 1 to 50	88	do	do	905	61.2
21	do	[7] 2 to 50	88	do	do	1,320	98.4
22	Check		88		do	2,269	11.1

[1] No. 21. (See p. 32.)
[2] No. 20.
[3] Commercial spreader containing 20 to 25 per cent casein.
[4] No. 16.
[5] No. 17.
[6] No. 15.
[7] Pounds to gallons.

TABLE 21.—*Laboratory tests of miscellaneous sprays on the European red mite, Yakima, Wash., 1923, 1924, and 1925*

[Tests 1 to 3 were made in 1923; tests 4 to 6 were made in 1924; tests 7 to 10 were made in 1925]

Test No.	Material used	Dilution[1]	Maximum temperature	Date trees were—		Mites examined	Mites killed
				Sprayed	Examined		
			°F.			*Number*	*Per cent*
1	Calcium caseinate (casein spreader) [2]	1 to 100	96	June 28	July 3	438	14.4
2	Water		74	June 22	June 23	86	4.7
3	Check		74		do	154	1.3
4	Washing soda (sodium carbonate)	1 to 100	88	July 8	July 9	508	56.1
5	Lye (sodium hydroxide, 94 per cent)	1 to 100	88	do	do	848	36.7
6	Check		88		do	2,269	11.1
7	Copper sulphate	1 to 200		July 30	Aug 7	687	20.5
8	do	1 to 100		do	do	584	19.5
9	Water			do	do	408	15.7
10	Check				do	450	9.1

[1] Pounds to gallons. [2] Commercial spreader containing 20 to 25 per cent casein.

COMPARISON OF SULPHUR AND OIL SPRAYS

Since the results obtained from sulphur and oil sprays have been given in separate tables in this bulletin, Table 22 is presented to give a direct comparison of the two types of materials. These tests were all made within 10 days under similar conditions, and it is believed that they show the relative value of the various materials.

TABLE 22.—*Comparison of the effectiveness of sulphur sprays and dusts and oil sprays against the European red mite, Yakima, Wash., 1923*

Test No.	Material used	Dilution	Maximum temperature	Date trees were—		Mites examined	Mites alive	Mites killed
				Sprayed	Examined			
		Per cent oil	°F.			*Number*	*Number*	*Per cent*
1	Lubricating-oil emulsion	0.25	96	June 28	June 30	163	32	80.4
2	do	.5	96	do	do	243	8	96.7
3	do	.67	96	do	do	236	0	100.0
		Dilution						
4	Lime-sulphur (32° Baumé concentrate)	[1] 1 to 50	74	June 22	June 23	127	15	88.2
5	Wettable sulphur	[2] 5 to 100	81	June 19	June 27	129	101	21.7
6	Flowers of sulphur, plus casein spreader (one-half pound to 100 gallons)	[2] 5 to 100	96	June 28	July 3	320	261	18.4
7	Sulphur flour, plus casein spreader (one-half pound to 100 gallons)	[2] 5 to 100	96	do	do	490	422	13.9
8	Dusting sulphur [3]		96	do	do	442	364	17.7
9	Check		96		do	388	354	8.8

[1] Gallons to gallons. [2] Pounds to gallons. [3] No. 19. (See p. 32.)

A second examination of some of the tests was made some days after the first, and the comparative number of live mites on 10 leaves, taken at random, was recorded. As shown in Table 23, a much smaller number of mites was present where the lubricating-oil emulsion had been used at a dilution of 0.5 or 0.67 per cent of oil than

where it had been used at a dilution of 0.25 per cent of oil, and the latter treatment had resulted in reducing the mites to about half the number present where no treatment was given. It was also found that the number of mites present was very much smaller where the lubricating-oil emulsion had been used than where lime-sulphur had been used. This was due not only to the larger number of mites killed by the oil but to its ovicidal value.

TABLE 23.—*A comparison of the effectiveness of oil and lime-sulphur sprays against the European red mite 12 to 17 days after spraying, Yakima, Wash., 1923*

Test No.	Material used	Dilution	Date trees were sprayed	Mites dead, first examination	Live mites on 10 leaves second examination	Interval between treatment and examination
		Per cent oil		*Per cent*	*Number*	*Days*
1	Lubricating-oil emulsion [1]	0.25	June 28	80.4	209	12
2	do	.5	do	96.7	85	12
3	do	.67	do	100.0	51	12
4	Check			7.8	410	12
5	Lubricating-oil emulsion [1]	.5	June 22	100.0	2	17
6	Lubricating-oil emulsion [2]	.5	do	98.5	8	17
		Dilution				
7	Lime-sulphur (32° Baumé concentrate)	[3] 1 to 50	do	88.2	136	17
8	Check			7.2	336	17

[1] No. 4 (red engine oil). (See p. 30.) [2] No. 4 (brown neutral oil). [3] Gallons to gallons.

ORCHARD TESTS

In 1923 an orchard test of lubricating-oil emulsion and of lime-sulphur was made on July 12. Two hundred gallons of each material was applied. The lubricating oil was used at a dilution of 0.67 per cent of oil. Part of it was applied with pilot rods and part with spray guns, and one tank containing in addition casein spreader and lead arsenate was also applied. An examination was made on the following day, the results of which are presented in Table 24. The pilot rods used in test 1 discharged a rather small quantity of spray, and it was difficult to wet both sides of the leaves with them. The use of the rods resulted in a mortality of 88.3 per cent of the mites, and the use of the spray guns in a mortality of 96.3 per cent. Test 3 is included to show what may happen when an emulsion breaks down. The water used was hard, containing a considerable quantity of calcium bicarbonate. This gradually broke down the soap in the emulsion and set free the oil. This reaction was probably hastened by the agitation of the emulsion in the spray tank. In test 3, which is simply an examination made on trees sprayed with the same materials used in test 2, but after it had separated, only 54.6 per cent of the mites were killed. The addition of spreader and lead arsenate to the oil spray (test 4) made no difference in the results obtained. Lime-sulphur at a dilution of 1 to 100 killed 68.1 per cent of the mites, and at a dilution of 1 to 50 it killed 93.1 per cent.

TABLE 24.—*Orchard tests of sprays against the European red mite, Yakima, Wash., 1923*

[Trees sprayed July 12; 10 leaves (250 to 800 mites) examined for each test July 13 to 17]

Test No.	Material used	Dilution	Equipment	Mites dead	
				July 13	July 17
		Per cent oil		*Per cent*	*Per cent*
1	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)[2]	0.67	Pilot rods.	88.3	
2	do	.67	Spray guns.	96.3	84.2
3	Material used in test 1 (emulsion separated)	.67	do	54.6	
4	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)[2], casein spreader,[3] plus lead arsenate,[4] 1 pound to 50 gallons.	.67	do	96.4	96.3
		Gallons			
5	Lime-sulphur (32° Baumé concentrate)	1 to 100	do	68.1	
6	do	1 to 50	do	93.1	
7	Check[5]			5.1	

[1] No. 2. (See p. 30.)
[2] No. 4.
[3] Commercial spreader containing 20 to 25 per cent casein.
[4] Commercial dry lead arsenate.
[5] Check examined July 9.

TABLE 25.—*Orchard tests of sprays against the summer eggs of the European red mite, Yakima, Wash., 1923*

[Trees sprayed July 12; 10 leaves (800 to 1,000 eggs) examined for each test July 17]

Test No.	Material used	Dilution	Eggs dead
		Per cent oil	*Per cent*
1	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)	0.67	76.6
2	Lubricating-oil (red engine)[1] emulsion (soap emulsifier), plus calcium-caseinate spreader[2] and lead arsenate,[3] 1 pound to 50 gallons	.67	81.1

[1] No. 2. (See p. 30.)
[2] Commercial spreader containing 20 to 25 per cent casein.
[3] Commercial dry lead arsenate.

An examination of the eggs was made in two of the foregoing tests five days after spraying. As shown in Table 25, the lubricating-oil emulsion killed 76.6 per cent of the eggs, and the same material, with the addition of casein spreader and lead arsenate, killed 81.1 per cent of the eggs. These figures are only approximate, as there were many hatched eggs on the leaves when the spray was applied, and these interfered with obtaining accurate results.

In 1924 a more comprehensive series of orchard tests was planned. The life-history studies in 1923 had shown that there was an interval of about 10 days between the hatching of the winter eggs and the deposition of the first summer eggs. The winter eggs were all hatched when the trees were in the pink, and the first summer eggs were deposited when the trees were in the proper condition for calyx spraying. It seemed possible, therefore, to use summer-strength lime-sulphur in the pink spray or in the calyx spray and obtain very nearly as good results as with oil, since the laboratory and orchard tests had shown that a high mortality of the mites resulted from the application of lime-sulphur. The inability of the lime-sulphur to kill the eggs would be of no consequence since very few eggs would be present. The results

of these tests are given in Table 26. In test 1 lime-sulphur at 1 to 50 was applied April 16, and in test 2 the same material was applied April 19. The hatching of the winter eggs was not complete until the 19th or 20th, and the latter application was thus more effective than the former. The first application seemed to have very little effect on the mites hatching after it was applied, for an examination made on May 2 showed a reduction in test 2 of 72.7 per cent in the number of mites present, as compared with the number in the check, and a reduction of only 41.5 per cent in test 1.

Part of plot 2 was sprayed again on May 7 with lime-sulphur, this being added to the regular calyx spray (test 2a), and plot 3 was also sprayed at that time (test 3). An examination of plot 2 on June 3 showed a reduction in test 2a of 96.6 per cent in the number of mites present, as compared with the number in the check, and a reduction in test 2 of 78 per cent. Plot 3 was not examined at this time, as it had been sprayed on June 2 with lubricating-oil emulsion. Plot 1 was sprayed with oil emulsion by the owner of the orchard on May 5 and again on June 4. On June 24, plot 1 (test 1a) showed a reduction in the number of mites of 72.3 per cent, whereas plot 3 (test 3), in which the oil had been more carefully applied, showed a reduction of 92.4 per cent.

It is thus apparent that lime-sulphur, applied for the control of apple powdery mildew in the pink or calyx spray, will also be very effective in controlling the European red mite. Two applications should be made, as it may be necessary to make the first one before all of the winter eggs have hatched. An application of lime-sulphur with the calyx spray, followed in three or four weeks by an application of lubricating-oil emulsion is also very effective. It is safer, however, to apply a pink spray of lime-sulphur if this material is to be used in the calyx spray, for some varieties of apples are likely to be injured by a calyx spray of lime-sulphur if it has not been used in the pink.

TABLE 26.—*Orchard tests of summer sprays of lime-sulphur and oil against the European red mite, Yakima, Wash., 1924*

Test No.	Material used	Dilution	Date trees were—		Mites on 50 leaves	Reduction compared with reduction in check	Mites on 50 check leaves
			Sprayed	Examined			
		Gallons to gallons			*Number*	*Per cent*	*Number*
1[1]	Lime-sulphur (28° Baumé concentrate.)	1 to 50	April 16 (pink)	May 2	1,260	41.5	2,155
1a	Lime-sulphur (28° Baumé concentrate).	do	Apr. 16				
		Per cent oil					
	Casein-oil emulsion[2]	0.5	May 5				
	do	do	June 4	June 24	981	72.3	3,544
		Gallons to gallons					
2	Lime-sulphur (28° Baumé concentrate.)	1 to 50	Apr. 19 (pink)	May 2	588	72.7	2,155
				June 3	431	78.0	1,968
2a	Lime-sulphur (28° Baumé concentrate.)	do	Apr. 19 (pink)				
	Lime-sulphur	do	May 7 (calyx)	June 3	67	96.6	1,968
3	Lime-sulphur (28° Baumé concentrate.)	do	May 7 (calyx)				
		Per cent oil					
	Casein-oil emulsion[2]	0.5	June 2	June 24	270	92.4	3,544

[1] The numbers are also the numbers of the plots.

[2] No. 5. (See p. 30.)

The percentage of mites killed by various applications of sprays with a power sprayer was also ascertained in 1924, the figures being given in Table 27. Lime-sulphur at a dilution of 1 to 50 killed practically the same number of mites as a lubricating-oil emulsion containing 0.5 per cent of oil (tests 1 and 2). The addition of casein spreader and of casein spreader and lead arsenate to the latter spray reduced its effectiveness slightly in tests 3, 4, and 5, made June 25. Three weeks after these materials had been used (July 14) there were only about one-fourth as many mites present as in unsprayed trees. A second series of tests, July 30, resulted in slightly better results from the oil emulsion diluted to 0.67 per cent of oil than from that diluted to 0.5 per cent of oil. Noticeably better control was obtained when spray guns were used (tests 8 and 8a) than when rods were used (tests 10 and 10a). The addition of caseinate spreader with these two methods of applying the spray gave better control in one case (test 11) and poorer in the other (test 9). An examination made nine days after spraying showed very little difference between the trees sprayed with spray guns and those sprayed with rods (tests 8 and 10), there being only one-seventh as many mites in either case as in unsprayed trees.

TABLE 27.—*Orchard tests of sprays against the European red mite, Yakima, Wash., 1924*

[In tests 1 to 6, 10 leaves (300 to 2,600 mites) were examined; in tests 7 to 12, 20 leaves (3,500 to 4,500 mites) were examined]

Test No.	Material used	Dilution	Date trees were—		Mites killed	Mites on 50 leaves		Reduction compared with check
			Sprayed	Examined		July 14	Aug. 8	
1	Lime-sulphur (30° Baumé concentrate)	1 to 50	May 7	May 9	*Per cent* 88.6	*Number*	*Number*	*Per cent*
2	Lubricating-oil (brown neutral)[1] emulsion (casein emulsifier)	*Per cent oil* 0.5	May 5	May 6	90.5			
3	do	.5	June 25	June 27	90.7	1,055		77.4
4	Material used in test 2, plus casein spreader,[2] 1½ pounds to 100 gallons	.5	do	do	88.9	952		79.6
5	Material used in test 2, plus lead arsenate,[3] 1 pound to 40 gallons, and casein spreader,[2] one-half pound to 100 gallons	.5	do	do	86.7	1,243		73.4
6	Check			do	.9	4,664		
7	Lubricating-oil (brown neutral)[1] emulsion (casein emulsifier), plus lead arsenate,[3] 1 to 50	.5	July 30	July 31	95.6		343	84.4
8	Lubricating-oil (brown neutral)[1] emulsion (casein emulsifier), applied with spray guns	.67	do	do	99.6		305	86.1
8a	Material used in test 8, applied to leaves taken from tops of trees	.67	do	do	100.0			
9	Material used in test 8, plus casein spreader,[2] one-half pound to 100 gallons applied with spray guns	.67	do	do	94.8			
10	Material used in test 8, applied with spray rods	.67	do	do	91.7		319	85.5
10a	Material used in test 8 applied to leaves taken from tops of trees	.67	do	do	83.1			
11	Material used in test 8, plus casein spreader,[2] one-half pound to 100 gallons applied with spray rods	.67	do	do	97.4			
12	Check			do	10.6		2,195	

[1] No. 1. (See p. 29.)
[2] Commercial spreader containing 20 to 25 per cent casein.
[3] Commercial dry lead arsenate.

SPRAY INJURY

The lubricating-oil emulsion applied as a dormant spray has not caused any injury when it was thoroughly emulsified and applied before the buds had separated. (Fig. 1.) If applied later than this, it will sometimes severely burn the foliage and the fruit buds and consequently reduce the crop.

FIG. 1.—Apple and pear twigs. Dormant oil sprays may be safely applied if buds are no further open than those on these twigs

In the case of most of the summer sprays tested, an examination was made a week or 10 days after spraying. A record was made of any injury caused to apple trees and this record is presented in Table 28. No injury of any consequence resulted from the use of lubricating-oil emulsions containing 0.67 per cent of oil or less. The injury increased as the quantity of oil was increased, the 2 per cent emulsion

causing about 10 per cent of the leaves to turn yellow and drop off. These were the oldest leaves, however. Some preliminary experiments made in September, 1922, in which similar sprays were used, resulted in a rather heavy dropping of the foliage, an indication that as the leaves grow older they are more susceptible to the oil. Miscible oils seemed to cause more injury than the emulsions.

TABLE 28.—*Record of injury caused by summer sprays used against the European red mite, Yakima, Wash., 1923 and 1925*

Referred to in— Table	Test No.	Material used	Dilution	Maximum temperature	Injury
			Per cent oil	°*F.*	
10	1	Lubricating-oil emulsion (soap emulsifier)[1]	0.5	92	No injury.
	2	Material used in test 1, plus cresol, 0.125 per cent	.5	92	Do.
	3	Material used in test 1, plus cresol, 0.25 per cent	.5	92	Do.
	4	Material used in test 1	1.0	92	A few leaves yellowed.
	5	....do	2.0	92	10 per cent of leaves yellowed.
	6	....do.[2]	.5	92	No injury.
	7	Commercial distillate-oil emulsion[3]	1.6	92	Do.
11	1	Lubricating-oil emulsion (soap emulsifier)[1]	.5	92	Do.
	2	Material used in test 1, plus cresol, 0.125 per cent	.5	92	Do.
	3	Material used in test 1	.67	92	Do.
	4	....do	.75	92	A few leaves yellowed.
	5	....do.[2]	.5	92	A few leaves burned.
	6	Commercial distillate-oil emulsion[3]	1.6	92	A few apples (in sun) spotted.
	8	Lubricating-oil emulsion (soap emulsifier)[1]	.25	97	No injury.
	9	....do	.5	97	A few leaves yellowed.
	10	....do	.67	97	Do.
13	1	Lubricating-oil emulsion (casein emulsifier)[4]	.25	95	No injury.
	2	....do	.5	95	Do.
	3	....do	.67	95	Do.
	4	....do	1.0	95	Slight burning of leaves.
	5	Lubricating-oil emulsion (soap emulsifier)[2]	.5	95	No injury.
	6	....do	.67	95	Do.
	7	....do.[1]	.5	95	Do.
	8	....do	.67	95	Do.
	9	Miscible oil[5]	.5	95	Slight leaf spotting.
	10	....do	.67	95	Considerable leaf burning.
14	1	Lubricating-oil emulsion (casein emulsifier)[4]	.25	91	No injury.
	2	....do	.5	91	Slight burning on southwest side.
	3	Lubricating-oil emulsion (soap emulsifier)[2]	.25	91	No injury.
	4	....do	.5	91	Considerable spotting on southwest side.
	5	Miscible oil[5]	.5	91	Slight burning on southwest side.
15	1	Lubricating-oil emulsion (casein emulsifier)[4]	.5	88	No injury.
	2	Material used in test 1, plus lead arsenate, 1 to 50	.5	88	Do.
	3	Material used in test 1, plus casein spreader, 1 to 200	.5	88	Do.
	4	....do	.67	88	Do
	5	Lubricating-oil emulsion (casein emulsifier),[4] plus lime-sulphur, 1 to 100	.25	88	Severe leaf burning.

[1] No. 4 (red engine oil). (See p 30.)
[2] No. 4 (brown neutral oil).
[3] No. 8.
[4] No. 5 (brown neutral oil).
[5] No. 10.

TABLE 28.—*Record of injury caused by summer sprays used against the European red mite, Yakima, Wash., 1923 and 1925*—Continued

Referred to in— Table	Test No.	Material used	Dilution	Maximum temperature	Injury
16	4	Lubricating-oil emulsion (kaolin emulsifier) [6]	0.67	90	No injury.
	5	Material used in test 4, plus (crystal oil) [7]	1.0	90	Do.
	6	Commercial oil (crystal) emulsion [8]	.85	90	Do.
	7	do	1.7	90	Slight leaf burning.
	8	Lubricating-oil emulsion (kaolin emulsifier) [6] and lime-sulphur, 1 to 100	.25	90	Severe leaf burning.
17	1	Dusting sulphur [9]		92	No injury.
	2	Sulphur and nocotine dust [10]		92	Do.
	4	Dusting sulphur [9]	*Dilution*	97	Do.
18	1	Lime-sulphur (32° Baumé concentrate)	[15] 1 to 50	92	Some leaves burned.
	2	Wettable sulphur	[14] 5 to 100	92	One apple burned (in sun).
	3	Flowers of sulphur	[14] 5 to 100	92	No injury.
	4	Sulphur flour	[14] 5 to 100	92	One apple burned (in sun).
	6	Lime-sulphur (32° Baumé concentrate)	[15] 1 to 50	92	No injury.
	8	do	[15] 1 to 100	97	Two leaves burned.
	9	do	[15] 1 to 50	97	Do.
	10	Flowers of sulphur	[14] 5 to 100	97	No injury.
	11	Sulphur flour	[14] 5 to 100	97	Do.
19	1	Lime-sulphur (28° Baumé concentrate)	[15] 1 to 75	95	Do.
	2	do	[15] 1 to 50	95	Do.
	4	do	[15] 1 to 50	95	Do.
	5	Soluble sulphur	[14] 4 to 50	91	Severe burning of leaves.
20	1	Nicotine dust [11]		92	No injury.
	2	Nicotine-sulphur dust [10]		92	Do.
	8	Nicotine sulphate, plus soap	[15] 1 to 1,000	95	Do.
	9	do	[15] 1 to 800	95	Do.
	10	Potash fish-oil soap [12]	[14] 2 to 50	95	Do.
	18	Nicotine sulphate; spreader	[15] 1 to 2,000	88	Do.
	19	Nicotine sulphate, plus soap	[15] 1 to 2,000	88	Do.
	20	Potash fish-oil soap [12]	[16] 1 to 50	88	Do.
	21	do	[14] 2 to 50	88	Do.
21	1	Casein lime [13]	[14] 1 to 100	97	Do.
	2	Water		97	Do.
	4	Washing soda	[14] 1 to 100	88	Do.
	5	Lye (NaOH)	[14] 1 to 100	88	Do.
	7	Copper sulphate	[14] 1 to 200	91	Do.
	8	do	[14] 1 to 100	91	Do.
24	[15] 1	Lubricating-oil emulsion (soap emulsifier) [17]	*Per cent oil* 0.67	97	Do.
	[15] 2	do	.67	97	Do.
	[15] 3	Lubricating-oil emulsion (emulsion separated)	.67	97	Do.
	[15] 4	Lubricating-oil emulsion, casein spreader and lead arsenate, 1 to 50	.67	92	Do.
	[15] 5	Lime-sulphur (32° Baumé concentrate)	*Dilution* [16] 1 to 100	92	Some apples burned; some burning of pear leaves and fruit.
	[15] 6	do	[16] 1 to 50	97	Same as above but more severe.

[6] No. 6 (brown neutral oil).
[7] No. 6 (crystal oil).
[8] No. 12.
[9] No. 19.
[10] No. 20.
[11] No. 21.
[12] No. 15.
[13] Commercial spreader containing 20 to 25 per cent casein.
[14] Pounds to gallons.
[15] Applied with power sprayer.
[16] Gallons to gallons.
[17] No. 4.

There were no appreciable signs that any of the sulphur sprays except the lime-sulphur spray and the soluble-sulphur spray, injured the foliage or fruit. The lime-sulphur spray usually caused some leaf burning and an occasional burned spot on an apple exposed to the hot sun. (Fig. 2.) The soluble-sulphur spray produced severe leaf burning.

The addition of weak lime-sulphur to the summer oil spray severely burned the leaves in test 8, Table 16. The nicotine-and-soap sprays did no harm whatever.

FIG. 2.—Apple showing injury that often occurs as a result of applications of lime-sulphur in hot weather

Examination of many trees sprayed with power sprayers has shown that the danger of injury from the use of the weak lubricating-oil emulsions is very slight when the emulsions are properly made. Early in the season, when the fruit and foliage are tender, there will sometimes be a little injury. The leaves may be spotted somewhat, and some of the fruit may drop. If a dormant-strength lime-sulphur spray has been applied to the trees after the fruit buds have separated, as is very often done, some dropping of fruit buds may follow, and at times this dropping may be greatly increased if the summer

FIG. 3.—Apple with sunken brown spots resulting from an application of summer oil spray containing free oil

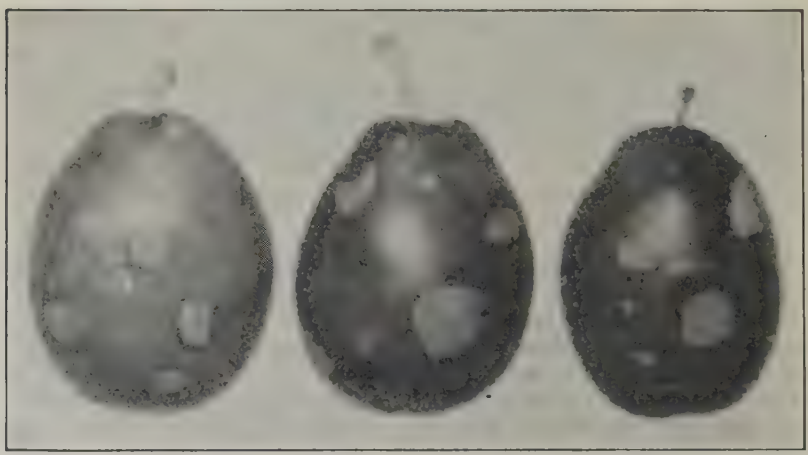

FIG. 4.—Prunes sprayed in May with a summer oil spray containing free oil. Photographed in July

oil sprays are applied early. Very little or no dropping occurs where summer oil sprays are used following dormant applications of oil. As a rule, also, oil sprays applied at the time of the cover sprays for the codling moth have produced little or no injury. Pears, prunes, and cherries sprayed at that time are unharmed. Peach foliage will be spotted at any time, and summer oil sprays should not be used on peach trees, particularly if made of oils of the red-engine or brown-neutral types.

It is imperative to use only thoroughly emulsified oils, whether they are homemade or commercially prepared, on account of the danger from free oil in the spray; for a small quantity of free oil in the spray tank will burn the fruit and foliage wherever it hits, particularly if the oils ordinarily employed for dormant sprays are used. Fruit so sprayed will sometimes be pitted with sunken brown spots (fig. 3), although these spots may disappear by the time the fruit is harvested.

FIG. 5.—Prunes sprayed in August with a summer oil spray. The spray has removed the bloom in spots and caused uneven coloring

On prunes, the burned spots are likely to result in russetted areas as the fruit grows. (Fig. 4). An oil spray applied to prunes after they have begun to color will remove the bloom in spots and result in uneven coloring. (Fig. 5). This is of no consequence if the fruit is to be dried, but it may affect the market value of fresh fruit.

COMPOSITION OF SPRAY MATERIALS

Almost all of the spray materials whose composition was not already known were analyzed by the Bureau of Chemistry. The formulas used, or the compositions or properties of the various sprays and materials are given below.

OILS

No. 1.—Brown neutral oil:

Volatility (four hours at 110° C.)	2.7 per cent.
Viscosity (Saybolt at 100° F.)	116 seconds.
Flash point (Pensky-Martin closed cup)	120° C.
Fire point (Pensky-Martin open cup)	167° C.
Specific gravity at 20° C.	0.922
Reaction to litmus	Neutral.

No. 2.—Red engine oil:

Volatility	0.43 per cent.
Viscosity	230 seconds.
Flash point	162° C.
Fire point	198° C.
Specific gravity	0.921
Reaction	Neutral.

No. 3.—Crystal oil:

Volatility	0.84 per cent.
Viscosity	122 seconds.
Flash point	174° C.
Fire point	190° C.
Specific gravity	0.871
Reaction	Neutral.
Unsulphonated residue (on 5 c. c.)	95.2 per cent.

OIL EMULSIONS AND MISCIBLE OILS

No. 4.—Lubricating-oil emulsion (soap emulsifier). Made according to the Government formula.[5]

Oil	2 gallons.
Water	1 gallon.
Potash fish-oil soap	2 pounds.

These materials are heated until the soap is dissolved and the mixture comes to a boil. The mixture is then immediately pumped twice with a bucket pump or other pump, using about 60 pounds pressure.

No. 5.—Lubricating-oil emulsion (casein emulsifier). Made according to the Missouri experiment station formula.[6]

Oil	2 gallons.
Water	1 gallon.
Casin spreader	4 ounces.

The spreader is thoroughly mixed with the water, the oil is added, the mixture stirred, and then pumped three times with a bucket pump or other pump, the materials being forced through a spray nozzle at from 150 to 200 pounds pressure.

No. 6.—Lubricating-oil emulsion (kaolin emulsifier). Made according to a formula developed by W. W. Yothers.[7]

Oil	2 gallons.
Water	1 gallon.
Kaolin	2⅔ pounds.

Add the kaolin to the water and let it come into suspension without stirring. Add the oil and pump twice with a bucket pump or other pump through a nozzle at about 100 pounds pressure.

No. 7.—Commercial lubricating-oil emulsion. (Analysis made by Bureau of Chemistry.) This was sold in the form of a miscible oil.

	Per cent
Water	2.1
Phenols	5.9
Fatty anhydride	3.9
Alkali	0.4
Mineral oil	87.7

(The oil was very similar to the brown neutral oil in No. 1.)

No. 8.—Commercial distillate-oil emulsion. This was in the form of a miscible oil. No analysis was made, but according to the label it contained water, soap, cresol, and 83 per cent of distillate oil.

---

[5] ACKERMAN, A. J. PRELIMINARY REPORT ON CONTROL OF SAN JOSE SCALE WITH LUBRICATING-OIL EMULSION. U. S. Dept. Agr. Circ. 263, 18 p., illus. 1923.

[6] BURROUGHS, A. M. A NEW METHOD OF MAKING ENGINE-OIL EMULSIONS. Missouri Agr. Expt. Sta. Bul. 205, 8 p., illus. 1923.

YOTHERS, W. W. COLD PROCESS OIL EMULSIONS. Jour. Econ. Ent. 18:545–546. 1925.

No. 9.—Miscible oil A.

	Per cent
Water	23.10
Dry soap	5.36
Cresol	14.30
Oil	57.24

(The oil used was the red engine oil of No. 2.)

No. 10.—Miscible oil B.

	Per cent
Water	4.5
Dry soap	4.7
Cresol	5.6
Oil	85.2

(The oil used was the brown neutral oil of No. 1.)

In making miscible oil, the ingredients must be accurately measured. The soap used is a potash fish-oil soap, such as described in No. 15. The quantity of water in it must first be determined and enough added to make up the quantity called for above. The cresol (cresylic acid, 97–99 per cent, pale) is then added and these ingredients are stirred, with gentle heat if necessary, until they are thoroughly mixed and uniformly clear. The oil is then added and thoroughly stirred. The resulting miscible oil should be as clear as the pure oil, and no sediment should separate out other than the few impurities in the soap, nor should any free oil collect at the top. A naphthene base oil must be used with this formula.

No. 11.—Commercial spray oil. (Analysis made by Bureau of Chemistry.)

	Per cent
Mineral oil	79. 7
Acid material	15. 7
Sodium oxide	1. 6
Water	1. 5

(In effect, this is a miscible oil.)

No. 12.—Commercial lubricating-oil emulsion. (Analysis made by Bureau of Chemistry.) This was sold in the form of an emulsion.

	Per cent
Water	13. 6
Oil	85. 0
Ammonia	0. 07
Emulsifier, etc	1. 33

(The oil used in making this emulsion is very similar to the crystal oil in No. 3.)

No. 13.—Lubricating oil-fatty-acid emulsion.

Oil	2 gallons.
Fatty acid (see formula)	2¾ pounds.
Caustic potash (commercial)	9 ounces.
Kerosene	2½ pints.
Water	2 gallons.

(This emulsion was made in a similar manner to that in No. 14.)

MISCELLANEOUS SPRAYS

No. 14.—Fatty-acid emulsion. The fatty acid used is a commercial mixture containing crude lauric acid, and is known as double distilled cocoanut fatty acid. In emulsifying it, the following formula, suggested by Siegler and Popenoe,[8] was employed.

Fatty acid	200 c. c.
Gasoline	200 c. c.
Water	525 c. c.
Glue (granular)	100 gm.

The fatty acid is first melted, and after it has been removed from the fire the gasoline is added and the mixture stirred until it is homogeneous. The glue is then dissolved in the water, with heat, poured into the other mixture, stirred, and while still hot, pumped twice at ordinary pressure through a spray pump.

[8] SIEGLER, E. H., and POPENOE, C. H. SOME INSECTICIDAL PROPERTIES OF THE FATTY-ACID SERIES. Jour. Agr. Research (1924) 29 : 259–261. 1925.

No. 15.—Fish-oil soap. The soap used was a potash fish-oil soap analyzed as follows:

	Per cent
Water	22. 5
Fatty anhydrides	66. 0
Alkali (K_2O)	11. 4

No. 16.—Nicotine and casein solution. This was prepared by adding a free nicotine preparation containing 40 per cent nicotine to casein at the rate of 2.5 c. c. to 1 gm. A small quantity of water was also added when mixing, and the material was then diluted as desired.

No. 17.—Commercial nicotine-creosote preparation. This material was labeled as follows:

Active ingredients:	Per cent
Nicotine sulphate	45. 00
Cyanide of sodium	12. 38
Creosote	22. 28
Inert ingredients	20. 34

No. 18.—Colloidal sulphur. This was prepared according to the formula used by Fisher [9] in experimental work in controlling the apple powdery mildew. This is as follows: "Dissolve one-half pound of cheap glue in hot water and add to 50 gallons of water in the spray tank. With the agitator running, add 1½ gallons of commercial lime-sulphur solution; then add commercial sulphuric acid until the yellow color is almost but not entirely replaced by white. It usually requires about 0.9 pint of sulphuric acid for 1½ gallons of lime-sulphur solution."

No. 19.—Dusting sulphur. This was a commercially prepared material labeled as follows:

	Per cent
Active ingredients, sulphur, not less than	89
Inert ingredients, not more than	11

No. 20.—Sulphur and nicotine dust.—This was a commercially prepared material labeled as follows:

Active ingredients:	Per cent
Sulphur, not less than	61. 0
Nicotine, not less than	2. 5
Inert ingredients, including hydrated lime, not more than	37. 5

No. 21.—Nicotine dust. This was a commercially prepared material labeled as follows:

	Per cent
Active ingredients, nicotine, not less than	2
Inert ingredients, not more than	98

SUMMARY AND CONCLUSIONS

The serious damage caused by fruit-tree mites, particularly the European red mite (*Paratetranychus pilosus* C. & F.), in the Pacific Northwest and elsewhere has led to a study of methods for their control.

Tests of dormant sprays have shown that lime-sulphur is of little value in the control of the winter eggs of the European red mite or of the brown mite (*Bryobia praetiosa* Koch). Lubricating-oil emulsions and miscible oils at dilutions of 2, 3, and 4 per cent of oil prevented more than 95 per cent of the eggs from hatching in most cases. Orchard tests indicated that a spray containing 3 per cent of oil was more efficacious than a 2 per cent spray. Infestations of mites were noticeably less on oil-sprayed trees than on those sprayed with lime-sulphur.

Summer sprays or dusts of sulphur gave very unsatisfactory control of the European red mite, but sulphur dust controlled the

[9] FISHER, D. F. APPLE POWDERY MILDEW AND ITS CONTROL IN THE ARID REGIONS OF THE PACIFIC NORTHWEST. U. S. Dept. Agr. Bul. 712, 28 p., illus. 1918.

two-spotted mite (*Tetranychus bimaculatus* Harvey) very well in a single test.

Summer-strength lime-sulphur killed most of the mites but very few eggs. When applied at the time of the pink and calyx sprays very good control resulted, since practically no eggs are present on the trees at that time. The effect of later applications was not nearly so lasting as that of oil sprays.

Lubricating-oil sprays, made from brown neutral, red engine, or crystal oils and used at dilutions containing 0.5 or 0.67 per cent of oil, have given very good results against the mites. These sprays have killed practically 100 per cent of the mites and most of the summer eggs. They are thus superior to lime-sulphur.

Of the miscellaneous sprays tested, the only one that was of any promise was the potash fish-oil soap. Used at the rate of 2 pounds to 50 gallons, this killed 90 to 99 per cent of the mites, but not very many eggs. It would perhaps be of use in spraying tender foliage that would be injured by oil sprays.

Nicotine sulphate killed less than 50 per cent of the mites, for the most part, except when used in combination with the potash fish-oil soap, when the control was excellent.

No injury of any consequence resulted from the use of dormant lime-sulphur or from dormant oil sprays, if used before the fruit buds separated.

Sulphur sprays or dusts used on the foliage did no particular harm. Summer-strength lime-sulphur burned the leaves slightly and sometimes burned fruits exposed to the sun.

Lubricating-oil sprays, used at strengths of 0.5 or 0.67 per cent of oil on the trees in foliage, caused no injury of any consequence to apple, pear, prune, or cherry, if the oils were thoroughly emulsified. Peach foliage was invariably spotted by oil sprays. Free oil spotted the fruit and foliage of any variety. Emulsions made of the crystal oil appeared to be safer to use than those made of brown neutral or red engine oils.

KEY TO THE TABLES OF SPRAY MATERIALS USED IN THIS BULLETIN

Reference	*Table No.*
Casein spreader (calcium caseinate)	12, 13, 14, 15, 16, 20, 21, 24, 25, 27, 28
Copper sulphate	21, 28
Cresol	1, 4, 7, 10, 11, 28
Fatty acid	16
Lime-sulphur	1, 2, 3, 4, 5, 6, 7, 8, 9, 18, 19, 22, 23, 24, 26, 27, 28
Lubricating-oil emulsion (casein emulsifier)	2, 3, 6, 8, 9, 13, 14, 15, 16, 26, 27, 28
Lubricating-oil emulsion (kaolin emulsifier)	16, 28
Lubricating-oil emulsion (soap emulsifier)	1, 2, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 22, 23, 24, 25, 28
Lubricating-oil emulsion and lime-sulphur	3, 15, 16, 28
Lye	21, 28
Miscible oil	2, 6, 8, 9, 13, 14, 28
Nicotine caseinate	20
Nicotine dust	20, 28
Nicotine sulphate	8, 9, 20, 28
Nicotine and sulphur dust	17, 20, 28
Oil, brown neutral	2, 3, 7, 8, 9, 10, 11, 13, 14, 15, 16, 23, 27, 28
Oil, crystal	16, 28
Oil, distillate	1, 7, 10, 11, 28
Oil, kerosene	1
Oil, red engine	2, 7, 8, 9, 10, 11, 12, 13, 23, 24, 25, 28
Soap, potash fish-oil	8, 9, 20, 28
Sulphur, colloidal	18
Sulphur, dusting	17, 22, 28
Sulphur, flour	18, 22, 28
Sulphur, flowers of	18, 22, 28
Sulphur and nicotine dust	17, 28
Sulphur, soluble	19, 28
Sulphur, wettable	18, 22, 28
Washing soda	21, 28
Water	21, 28

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

November 8, 1927

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension	C. W. WARBURTON.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Director of Information	NELSON ANTRIM CRAWFORD.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	C. W. LARSON, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	LLOYD S. TENNY, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food, Drug, and Insecticide Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This bulletin is a contribution from

Bureau of Entomology	C. L. MARLATT, *Chief.*
Division of Deciduous Fruit Insects	A. L. QUAINTANCE, *in Charge.*

34

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
U.S.GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY